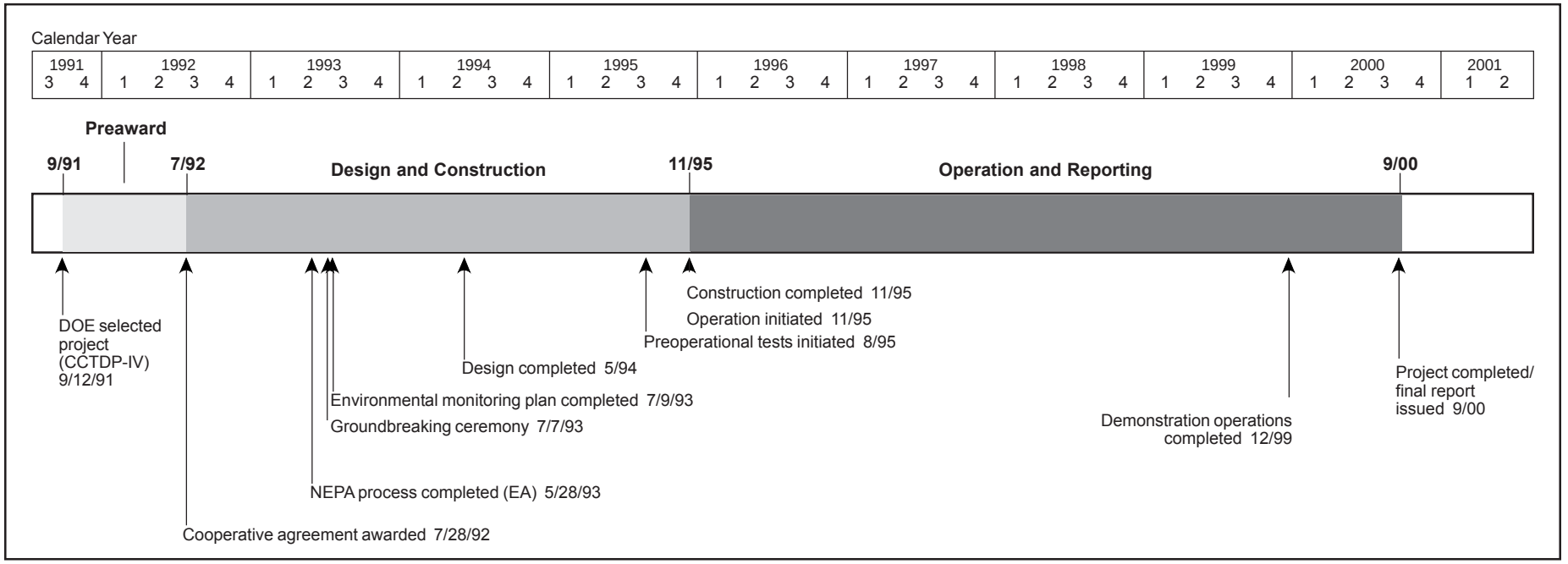

Results Summary

Environmental

- The SO_2 capture efficiency was greater than 99%, keeping SO_2 emissions consistently below 0.1 lb/10^6 Btu and reaching as low as 0.03 lb/10^6 Btu. Sulfur-based pollutants were transformed into 99.99% pure sulfur, a highly valued by-product—33,388 tons produced during the demonstration period.
- The NO_x emissions were 0.15 lb/10^6 Btu, which meets the 2003 target emission limits for ozone non-attainment areas, or 1.09 lb/MWh, and exceeds performance requirement based on the New Source Performance Standard of 1.6 lb/MWh.
- Particulate emissions were below detectable limits.
- Carbon monoxide emissions, averaging 0.05 lb/10^6 Btu, were well within industry standards.
- Coal ash was converted to a low-carbon vitreous slag, impervious to leaching and valued as an aggregate in construction or as grit for abrasives and roofing materials; and trace metals from petroleum coke were also encased in an inert vitreous slag.

Operational

- Over the course of the demonstration, the IGCC unit operated on coal for over 15,000 hrs, processed over 1.5 million tons of coal, and produced over 23 trillion Btu of syngas and 4 million MWh of electricity.
- Design changes in the first year included: (1) using a less tenacious refractory in the second-stage gasifier and changing the flow path geometry to eliminate ash deposition on the second-stage gasifier walls and downstream piping; (2) changing to improved metallic candle filters to prevent particulate breakthrough in the hot gas filter; and (3) installing a wet chloride scrubber and a COS catalyst less prone to poisoning to eliminate chloride and metals poisoning of the COS catalyst.
- The second year identified cracking in the gas turbine combustion liners and tube leaks in the heat recovery steam generator (HRSG). Resolution involved replacement of the gas turbine fuel nozzles and liners and modifications to the HRSG to allow for more tube expansion.
- The third year was essentially trouble free and the IGCC unit underwent fuel flexibility tests, which showed that the unit operated trouble free, without modification, on a second coal feedstock, a blend of two different Illinois #6 coals, and petroleum coke. Overall thermal performance actually improved during petroleum coke operation, increasing plant efficiency from 39.7% to 40.2%.
- In the fourth year, the gas turbine incurred damage to the rotor and stator in rows 14 through 17 of the air compressor causing a 3-month outage. But over the four years of operation, availability of the gasification plant steadily improved reaching 79.1% in 1999.

Economic

- The overall cost of the IGCC plant was $417 million, which equates to about $1,590/kW in 1994 dollars. For an equivalent greenfield project the cost was estimated at $1,700/kW. Capital cost estimates for a new 285 MWe (net) greenfield IGCC plant incorporating lessons learned, technology improvements, and a heat rate of 8,526 Btu/kWh are $1,318/kW (2000$) for a coal-fueled unit and $1,260 (2000$) for a petroleum coke-fueled unit.

Project Summary

The Wabash River Coal Gasification Repowering Project repowered a 1950s vintage pulverized coal-fired plant, transforming the plant from a nominally 33% efficient, 90-MWe unit into a nominally 40% efficient, 262-MWe (net) unit. Cinergy, PSI's parent company, dispatches power from the project, with a demonstrated heat rate of 8,910 Btu/kWh (HHV), second only to their hydroelectric facilities on the basis of environmental emissions and efficiency.

Beyond the integration of an advanced gasification system, a number of other advanced features contributed to the high energy efficiency. These included: (1) hot/dry particulate removal to enable gas cleanup without heat loss, (2) integration of the gasifier high-temperature heat recovery steam generator with the gas turbine-connected HRSG to ensure optimum steam conditions for the steam turbine, (3) use of a carbonyl sulfide (COS) hydrolysis process to enable high-percentage sulfur removal, (4) recycle of slag fines for additional carbon recovery, (5) use of 95% pure oxygen to lower power requirements for the oxygen plant, and (6) fuel gas moisturization to reduce steam injection requirements for NO_x control.

Over the four-year demonstration period starting in November 1995, the facility operated on coal for more than 15,000 hours and processed over 1.5 million tons of coal to produce more than 23 trillion Btu of syngas. For several of the months, syngas production exceeded one trillion Btu. By the end of the demonstration, the 262-MWe IGCC unit had captured and produced 33,388 tons of sulfur.

Operational Performance

The first year of operation resolved problems with: (1) ash deposition on the second stage gasifier walls and downstream piping, (2) particulate breakthrough in the hot gas filter system, and (3) chloride and metals poisoning of the COS catalyst. Modifications to the second-stage refractory to avoid tenacious bonds with the ash and to the hot gas path flow geometry corrected the ash deposition problem. Replacement of the ceramic candle filters with metallic candles proved to be largely successful. A follow-on metallic candle filter development effort ensued using a hot gas slipstream, which resulted in improved candle filter metallurgy, blinding rates, and cleaning techniques. The combined effort all but eliminated downtime associated with the filter system by the close of 1998. Installation of a wet chloride scrubber eliminated the chloride problem by September 1996 and use of an alternate COS catalyst less prone to trace metal poisoning provided the final cure for the COS system by October 1997.

The second year of operation identified cracking problems with the gas turbine combustion liners and tube leaks in the HRSG. Replacement of the fuel nozzles and liners solved the cracking problem. Resolution of the HRSG problem required modification to the tube support and HRSG roof/penthouse floor to allow for more expansion.

By the third year, downtime was reduced to nuisance items such as instrumentation-induced trips in the oxygen plant and high-maintenance items such as replacement of high-pressure slurry burners every 40–50 days. In the third year, the IGCC unit underwent fuel flexibility tests. The unit operated effectively, without modification or incident, on a second coal feedstock, a blend of two different Illinois #6 coals, and petroleum coke (petcoke). These tests added to the fuel flexibility portfolio of the gasifier, which had previously processed both lignite and subbituminous coals during its earlier development. The overall thermal performance of the IGCC unit actually improved during petcoke operation. The unit processed over 18,000 tons of high-sulfur petcoke and produced 350 billion Btu of syngas. There was a negligible amount of tar production and no problems were encountered in removing the dry char particulate despite a higher dust loading. Exhibit 3-45 provides a summary of the thermal performance of the unit on both coal and petcoke.

The fourth year of operation was marred by a 3-month outage due to damage to the rotor and stator in rows 14 through 17 of the gas turbine air compressor. However, over the four years of operation, availability of the gasification plant steadily improved, reaching 79.1% in 1999. Exhibit 3-46 provides a summary of the production statistics during the demonstration period.

Environmental Performance

The IGCC unit operates with an SO_2 capture efficiency greater than 99%. As a result, SO_2 emissions are consistently below 0.1 lb/10^6 Btu of coal input, reaching as low as 0.03 lb/10^6 Btu. Moreover, the process transforms sulfur-based pollutants into 99.99% pure sulfur, a highly valued by-product, rather than a solid waste.

Moisturizing the syngas in combination with steam injection reduced NO_x emissions to the 0.15 lb/10^6 Btu requirement established by EPA for existing plants in ozone non-attainment areas. Because of the extreme particulate filtration necessary for combustion of the syngas in a gas turbine, particulate emissions were negligible, averaging

Exhibit 3-45
Wabash Thermal Performance Summary

	Design	Actual	
	Coal	Coal	Petcoke
Nominal Throughput, tons/day	2,550	2,450	2,000
Syngas Capacity, 10^6 Btu/hr	1,780	1,690	1,690
Combustion Turbine, MWe	192	192	192
Steam Turbine, MWe	105	96	96
Auxiliary Power, MWe	35	36	36
Net Generation, MWe	262	261	261
Plant Efficiency, % (HHV)	37.8	39.7	40.2
Sulfur Removal Efficiency, %	>98	>99	>99

0.012 lb/10^6 Btu. Also, carbon monoxide emissions were quite low, averaging 0.05 lb/10^6 Btu.

The ash component of the coal results in a low-carbon vitreous slag, impervious to leaching and valued as an aggregate in construction or as grit for abrasives and roofing materials. Also, the trace metal constituents in the petcoke were effectively captured in the slag produced.

Economic Performance

The overall cost of the IGCC demonstration plant was $417 million, which equates to about $1,590/kW in 1994 dollars. For an equivalent greenfield project, allowing for additional new equipment required, the installed cost was estimated at $1,700/kW. Costs include engineering, permitting, equipment procurement, project and construction management, construction, start-up, and hiring and training personnel.

In the final report, the participant estimates capital cost for a new 262-MWe greenfield IGCC plant incorporating lessons learned, technology improvements, and a heat rate of 8,250 Btu/kWh are $1,275/kW (2000$) for a coal-fueled unit and $1,150/kW (2000$) for a petroleum coke-fueled unit. In designing for petcoke, some equipment can be reduced in size and some eliminated.

More recent data developed by DOE shows that a 285-MWe (net) coal-fired greenfield IGCC plant with a heat rate of 8,526 Btu/kWh would cost $1,318/kW (2000$). A 291-MWe (net) petroleum coke-fired IGCC unit with a 8,400 Btu/kWh heat rate would cost $1,260/kW.

Annual fuel costs for the Wabash project ranged from $15.3–19.2 million, with an annual availability of 75% and using high-sulfur bituminous coal ranging from $1.00–1.25/$10^6$ Btu ($22–27/ton). Non-fuel operation and maintenance (O&M) costs for the syngas facility (excluding the power block) was 6.8% of installed capital based on 75% availability. O&M costs include operating labor and benefits, technical and administrative support on and off site, all maintenance, chemicals, waste disposal, operating services, supplies, and 5% of the total O&M cost for betterments. Projected O&M costs for a mature IGCC facility (including the power block) are 5.2% of installed capital.

Exhibit 3-46
Wabash River Coal Gasification Repowering Project
Production Statistics

Time Period	On Coal (Hr)	Coal Processed (tons)	On Spec. Gas (10^6 Btu)	Steam Produced (10^6 lb)	Power Produced (MWh)	Sulfur Produced (tons)
Start-up 1995	505	41,000[a]	230,784	171,613	71,000[a]	559
1996	1,902	184,382	2,769,685	820,624	449,919	3,299
1997	3,885	392,822	6,232,545	1,720,229	1,086,877	8,521
1998	5,279	561,495	8,844,902	2,190,393	1,513,629	12,452
1999[b]	3,496	369,862	5,813,151	1,480,908	1,003,853	8,557
Overall	15,067	1,549,561	23,891,067	6,383,767	4,125,278	33,388

[a]Estimates.
[b]The combustion turbine was unavailable from 3/14/99 through 6/22/99.

Commercial Applications

At the end of the demonstration in December 1999, Global Energy, Inc. purchased Dynegy's gasification assets and technology. Global Energy is marketing the technology under the name "E-Gas Technology™." The project is continuing to operate in commercial service as Wabash River Energy, Ltd., a subsidiary of Global Energy.

The immediate future for E-Gas Technology™ appears to lie with both foreign and domestic applications where low-cost feedstocks such as petroleum coke can be used and co-production options are afforded—bundled production of steam, fuels/chemicals, and electricity. Integration or association with refinery operations are examples. Factors favoring increased use of IGCC over time are continued improvement in IGCC cost and performance, projected increases in price differentials between coal and gas, and continued importance placed on displacement of petroleum in chemicals and fuels production.

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References

Wabash River Coal Gasification Repowering Project: Final Technical Report. Wabash River Coal Gasification Project Joint Venture. August 2000.

W*abash River Coal Gasification Repowering Project—Project Performance Summary.* U.S. Department of Energy. January 2002.

Wabash River Coal Gasification Repowering Project

Project completed

Participant

Wabash River Coal Gasification Repowering Project Joint Venture (a joint venture of Dynegy and PSI Energy, Inc.)

Additional Team Members

PSI Energy, Inc.—host

Dynegy (formerly Destec Energy, Inc., a subsidiary of Natural Gas Clearinghouse)—engineer and gas plant operator

Location

West Terre Haute, Vigo County, IN (PSI Energy's Wabash River Generating Station, Unit No. 1)

Technology

Integrated gasification combined-cycle (IGCC) using Global Energy's two-stage pressurized, oxygen-blown, entrained-flow gasification system—E-Gas Technology™

Plant Capacity/Production

296 MWe (gross), 262 MWe (net)

Coal

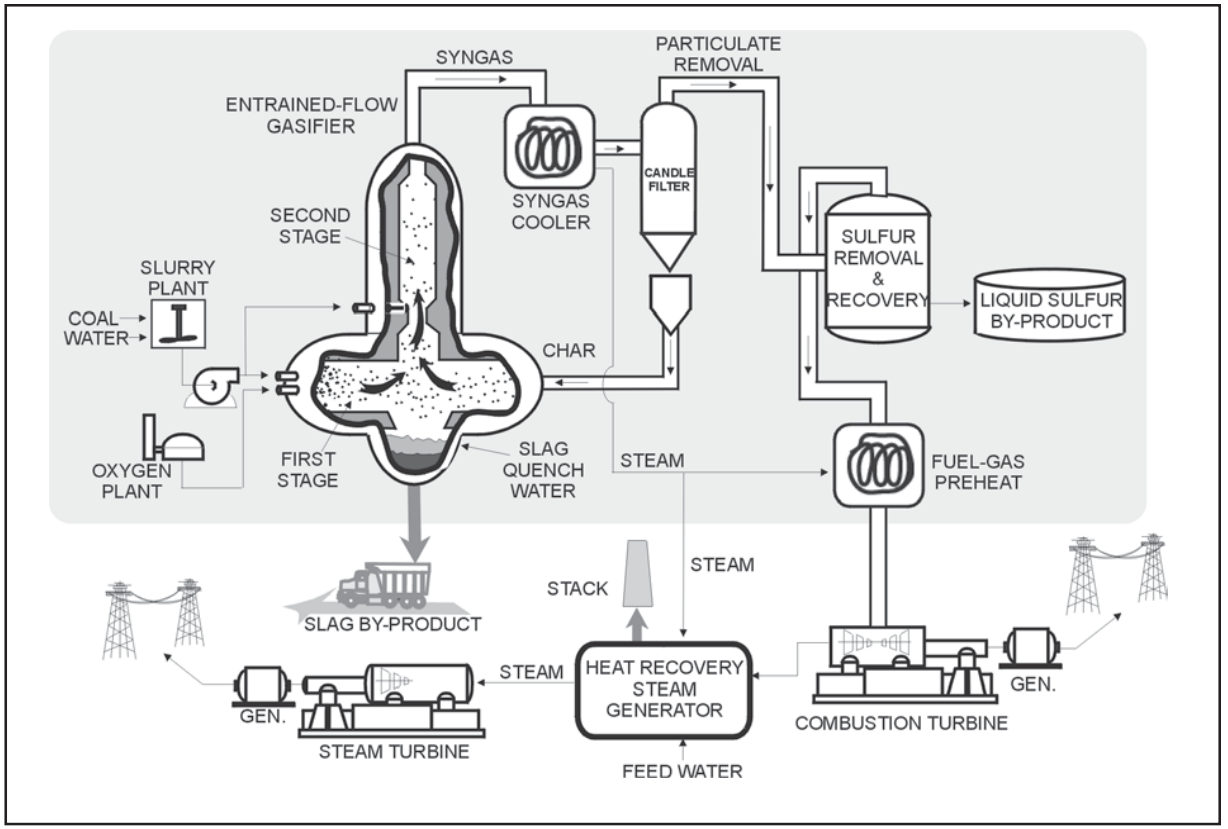
Illinois Basin bituminous (Petroleum coke also used)

Project Funding

Total	$438,200,000	100%
DOE	219,100,000	50
Participant	219,100,000	50

Project Objective

To demonstrate utility repowering with a two-stage, pressurized, oxygen-blown, entrained-flow IGCC system, including advancements in the technology relevant to the use of high-sulfur bituminous coal; and to assess long-term reliability, availability, and maintainability of the system at a fully commercial scale.



Technology/Project Description

The Destec, now E-Gas Technology™, process features an oxygen-blown, continuous-slagging, two-stage, entrained flow gasifier. Coal is slurried, combined with 95% pure oxygen, and injected into the first stage of the gasifier, which operates at 2,600 °F/400 psig. In the first stage, the coal slurry undergoes a partial oxidation reaction at temperatures high enough to bring the coal's ash above its melting point. The fluid ash falls through a tap hole at the bottom of the first stage into a water quench, forming an inert vitreous slag. The syngas flows to the second stage, where additional coal slurry is injected. This coal is pyrolyzed in an endothermic reaction with the hot syngas to enhance syngas heating value and improve efficiency.

The syngas then flows to the syngas cooler, essentially a fire tube steam generator, to produce high-pressure saturated steam. After cooling in the syngas cooler, particulates are removed in a hot/dry filter and recycled to the gasifier. The syngas is further cooled in a series of heat exchangers. The syngas is water-scrubbed to remove chlorides and passed through a catalyst that hydrolyzes carbonyl sulfide into hydrogen sulfide. Hydrogen sulfide is removed in the acid gas removal system using MDEA-based absorber/stripper columns. A Claus unit is used to produce elemental sulfur as a salable by-product. The "sweet" gas is then moisturized, preheated, and piped to the power block. The power block consists of a single 192-MWe General Electric MS 7001FA (Frame 7 FA) gas turbine, a Foster Wheeler single-drum heat recovery steam generator with reheat, and a 1952-vintage Westinghouse reheat steam turbine.